Micro- and meso-scale effects of forested terrain

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Micro- and meso-scale effects of forested terrain

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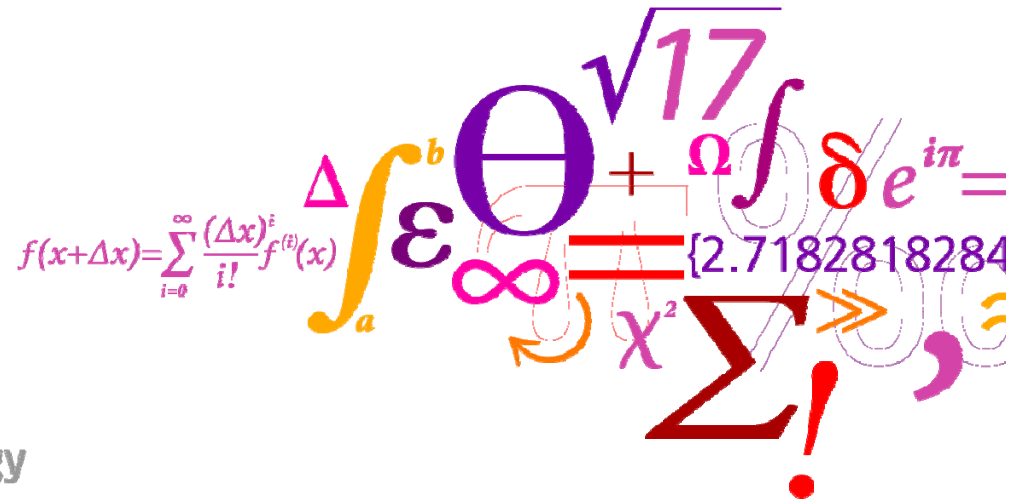

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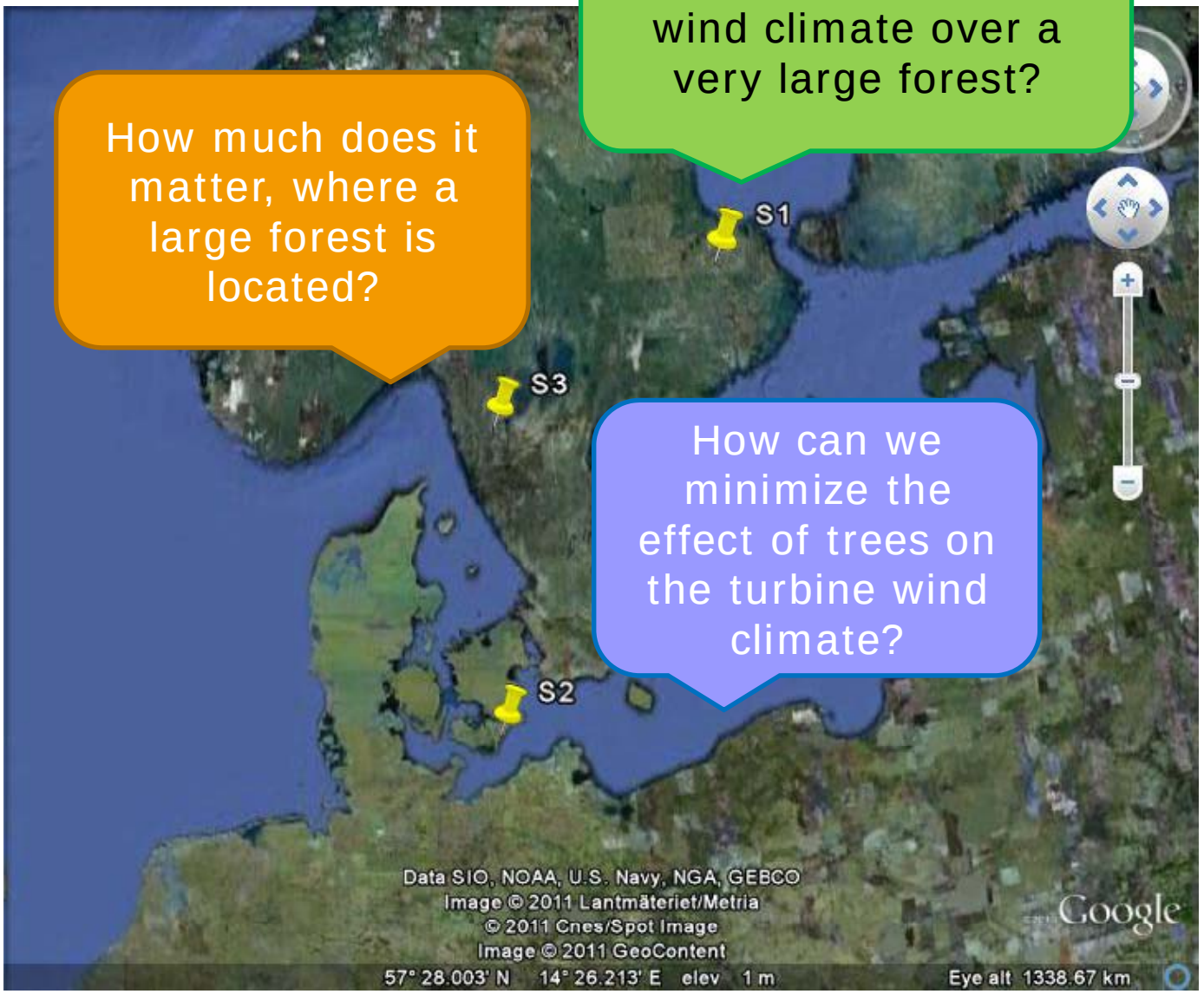
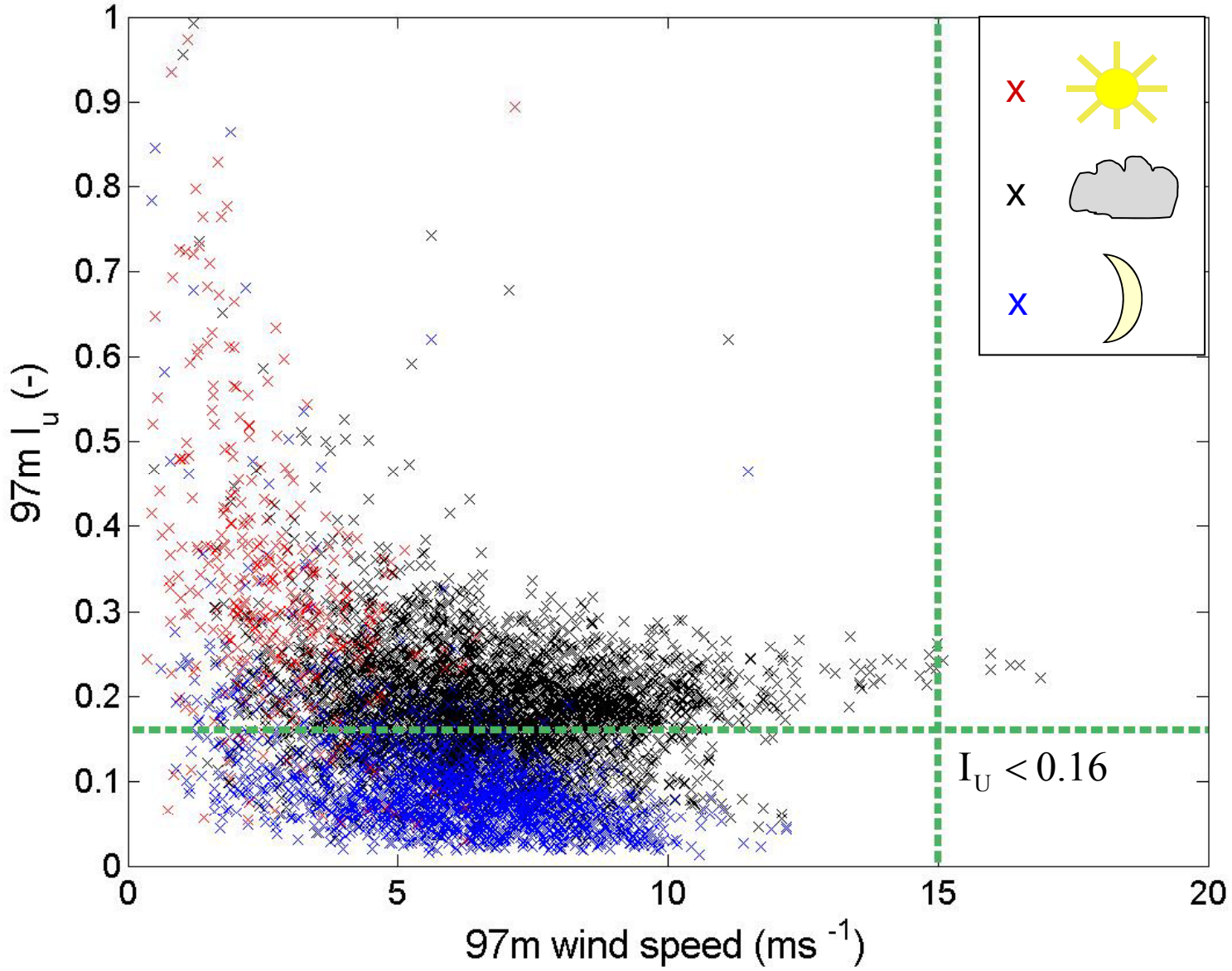
Sites


What characterizes the wind climate over a very large forest?
How much does it matter, where a large forest is located?
How can we minimize the effect of trees on the turbine wind climate?
S1
S2
S3
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2011 Lantmäteriet/Metria
© 2011 Cnes/Spot Image
Image © 2011 GeoContent
57° 28.003' N 14° 26.213' E elev 1 m
Eye alt 1338.67 km
Google

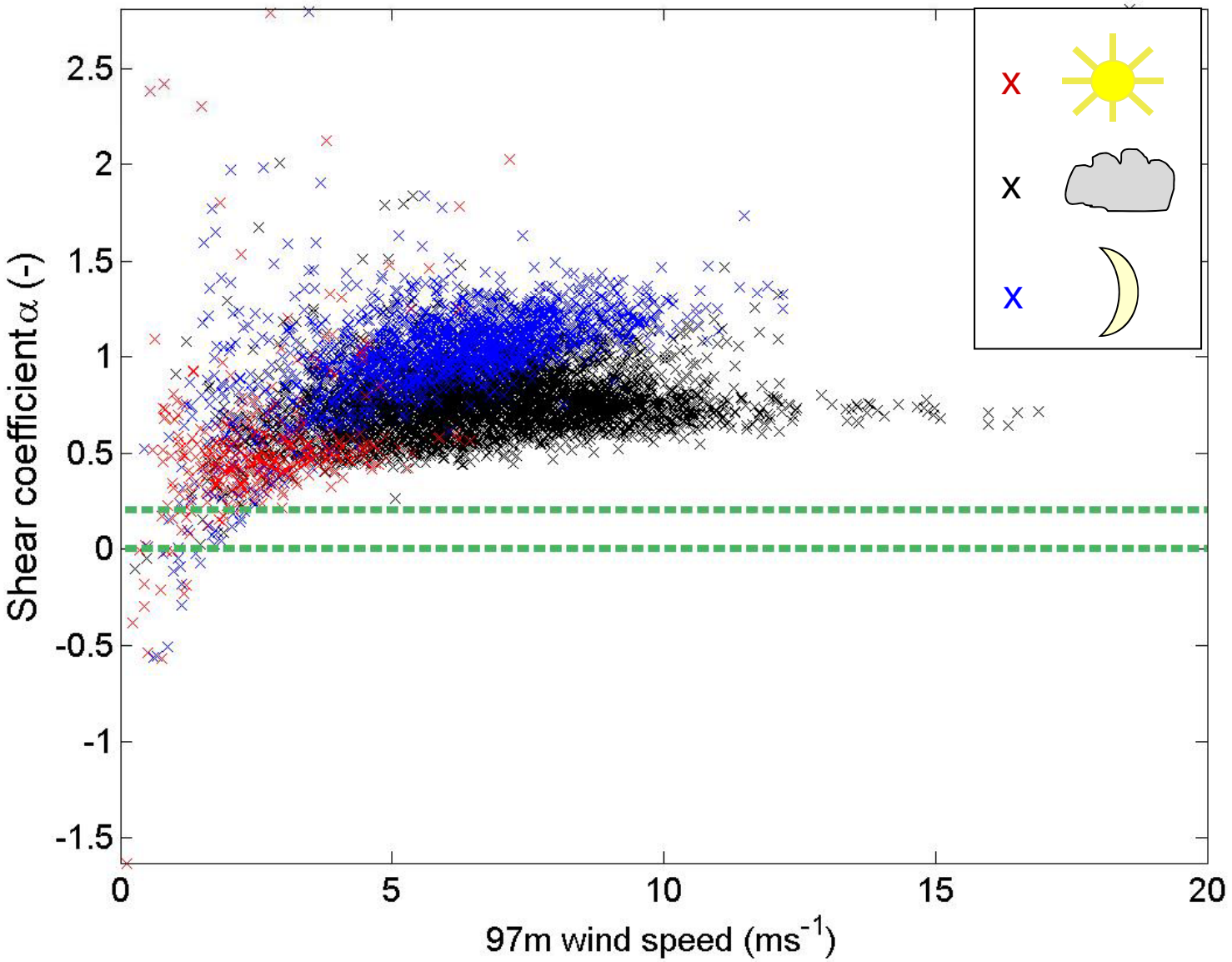
S1: 100m tall mast
Sonic anemometers at 33 and 97m
Forest height 25m (2000)

S1 turbulence intensity $I_U = \frac{\sigma_u}{U}$

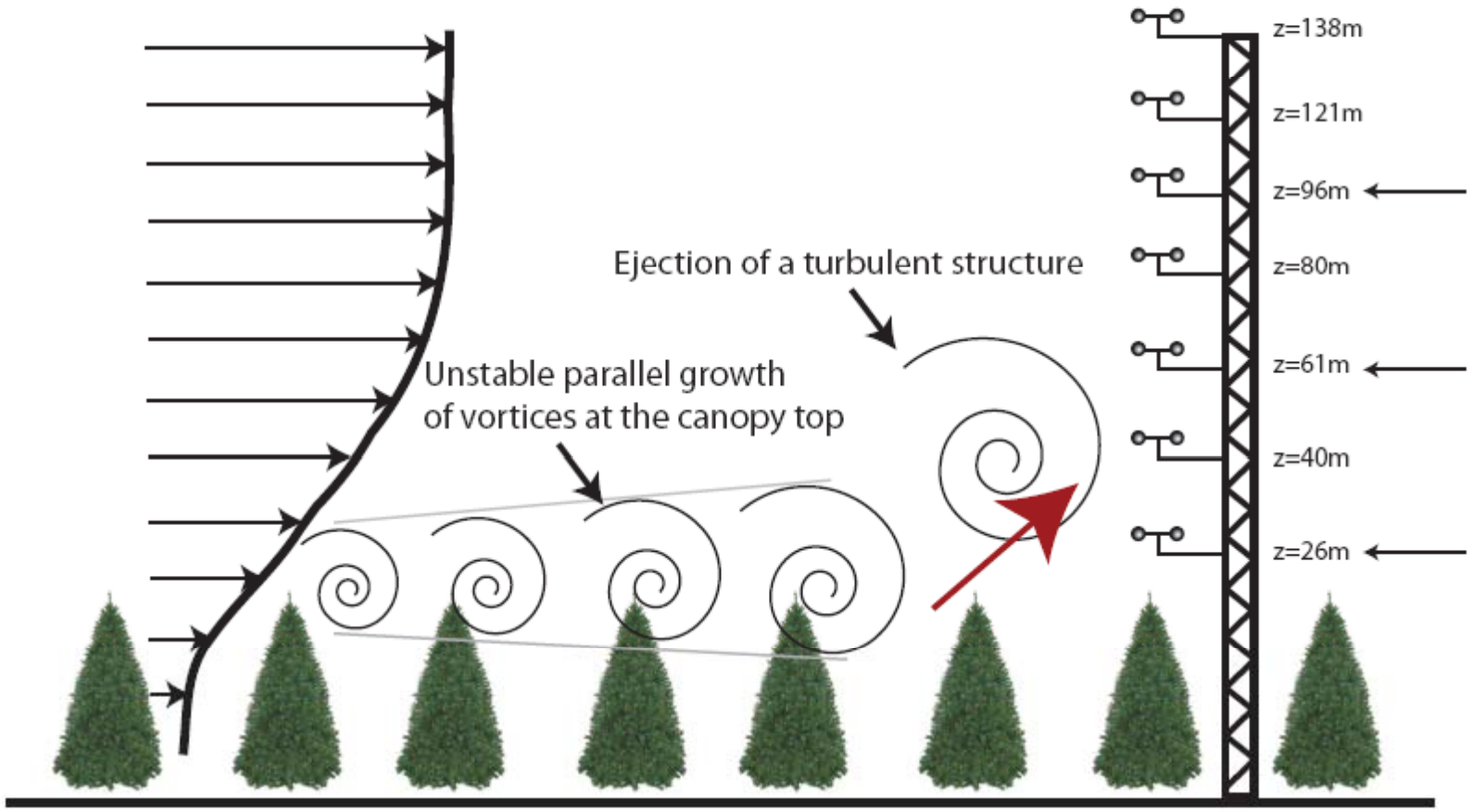


S1 shear

$$\frac{U}{U_{hub}} = \left(\frac{z}{z_{hub}} \right)^{\alpha}$$



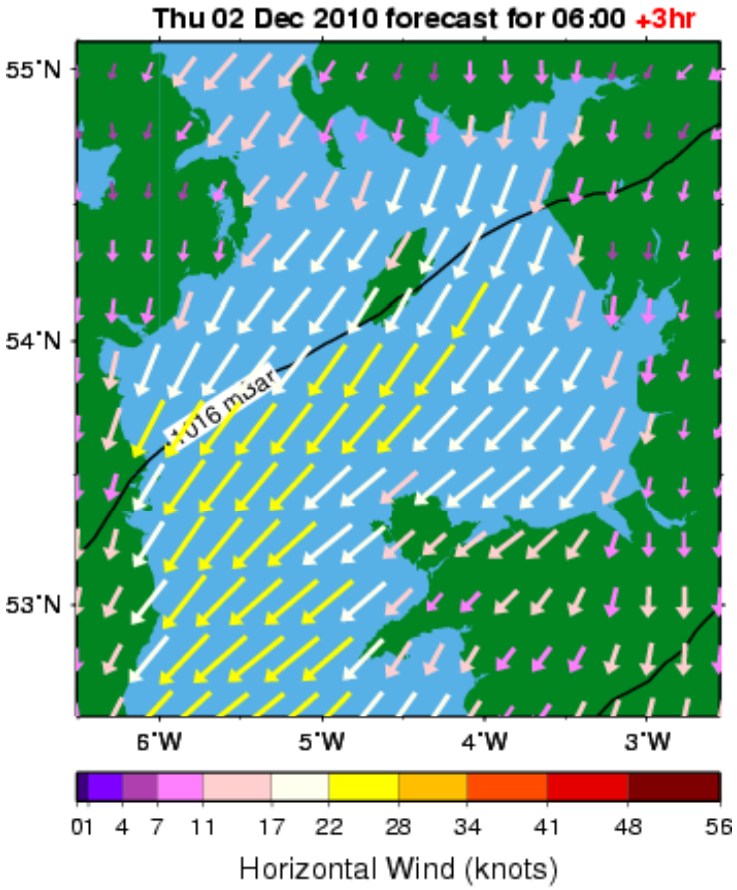
Turbulent structures in forested areas



Gust structure and generation in canopy flows, Segalini et al., PO 457

Siting challenge: large forested area like S1

- The turbine should be tall to avoid extreme shear, high turbulence and turbulent events near the surface.
- What is the wind resource in the range 100-250m?



Effects of ”weather” and land surface on flow.

The *meso-scale* flow models predict the daily cycle of temperature, wind, humidity up to about 15km.

The height of the boundary layer and surface energy balance are important.

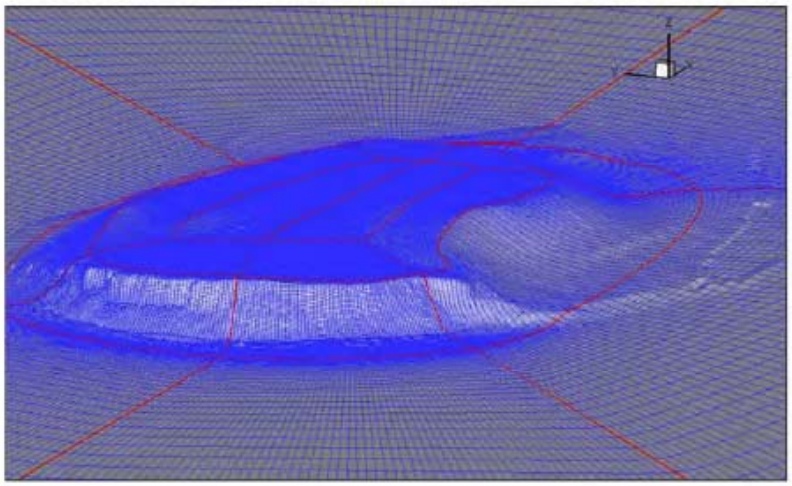
Forest is represented with a roughness, typically less than 1m

Resolution ~ 1km

Siting challenge: small forests

How can we minimize the effect of trees on the turbine wind climate?

We perform experiments with the aim of verifying and improving our micro-scale models.



Resolution ~ 1-10m

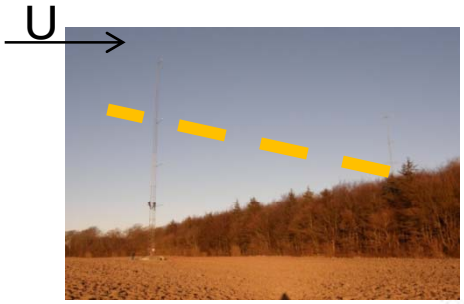
Micro-scale focus: the effect of terrain on flow, for example a forest edge, a hill or an escarpment.

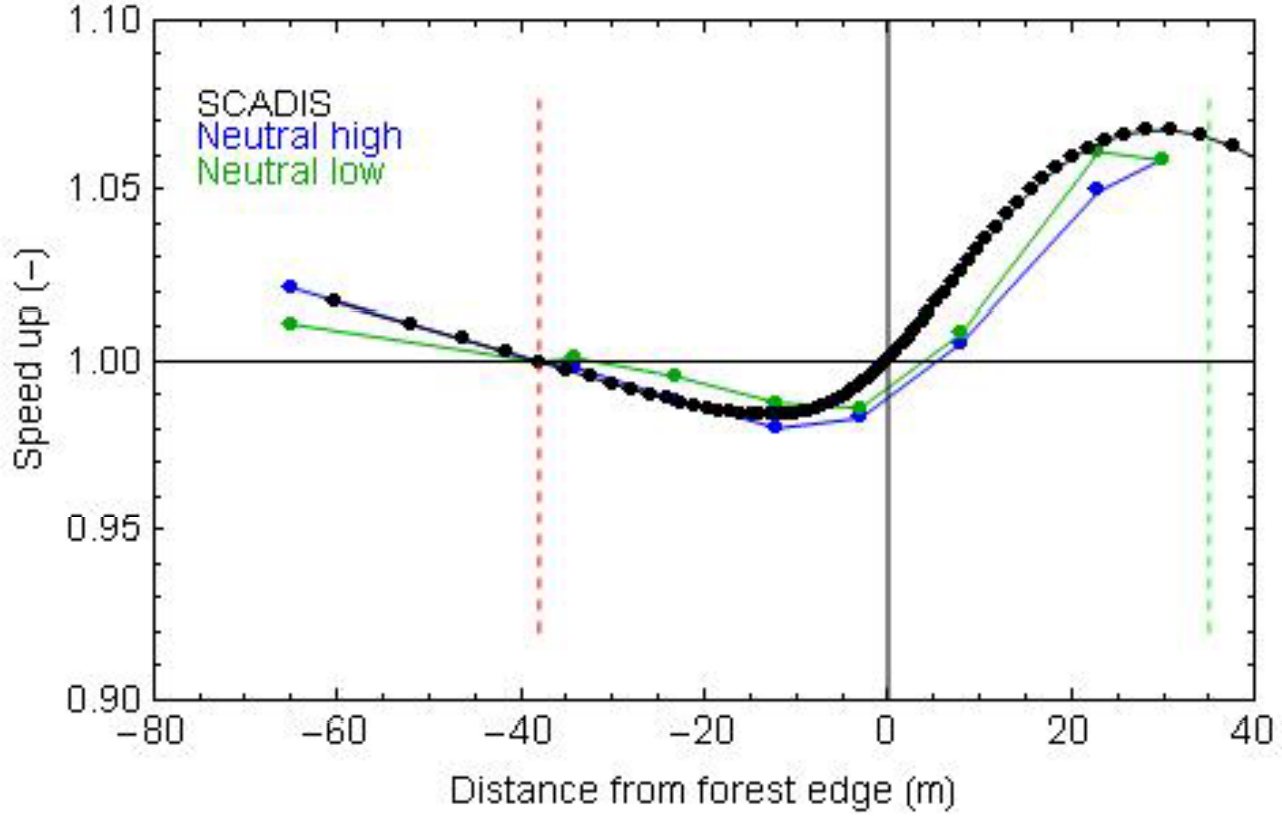
The *micro-scale* flow models *primarily* predict the flow when there is no temperature gradient.

The forest is represented as a distributed drag force.

S2: Two 45m masts
1 horizontally pointing lidar
Forest height 24m

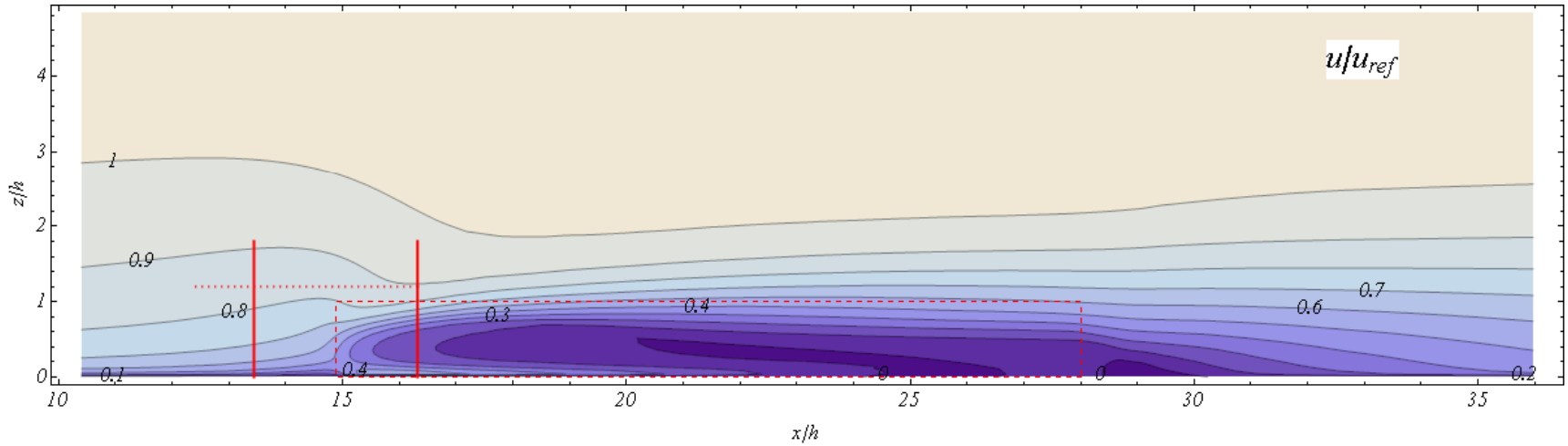
LIDAR and CFD modelling results





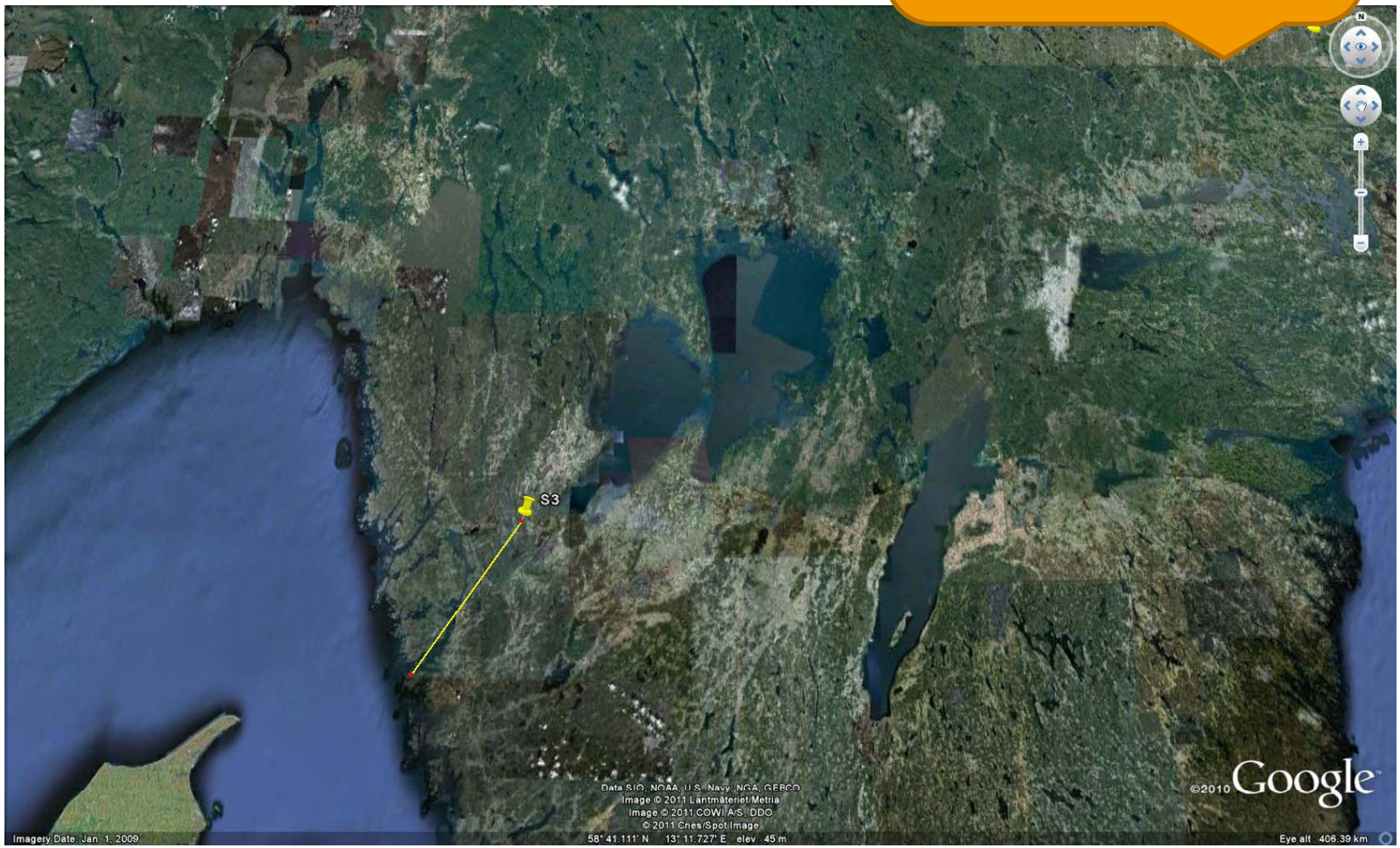
Micro-scale model applications

Optimized siting of turbines

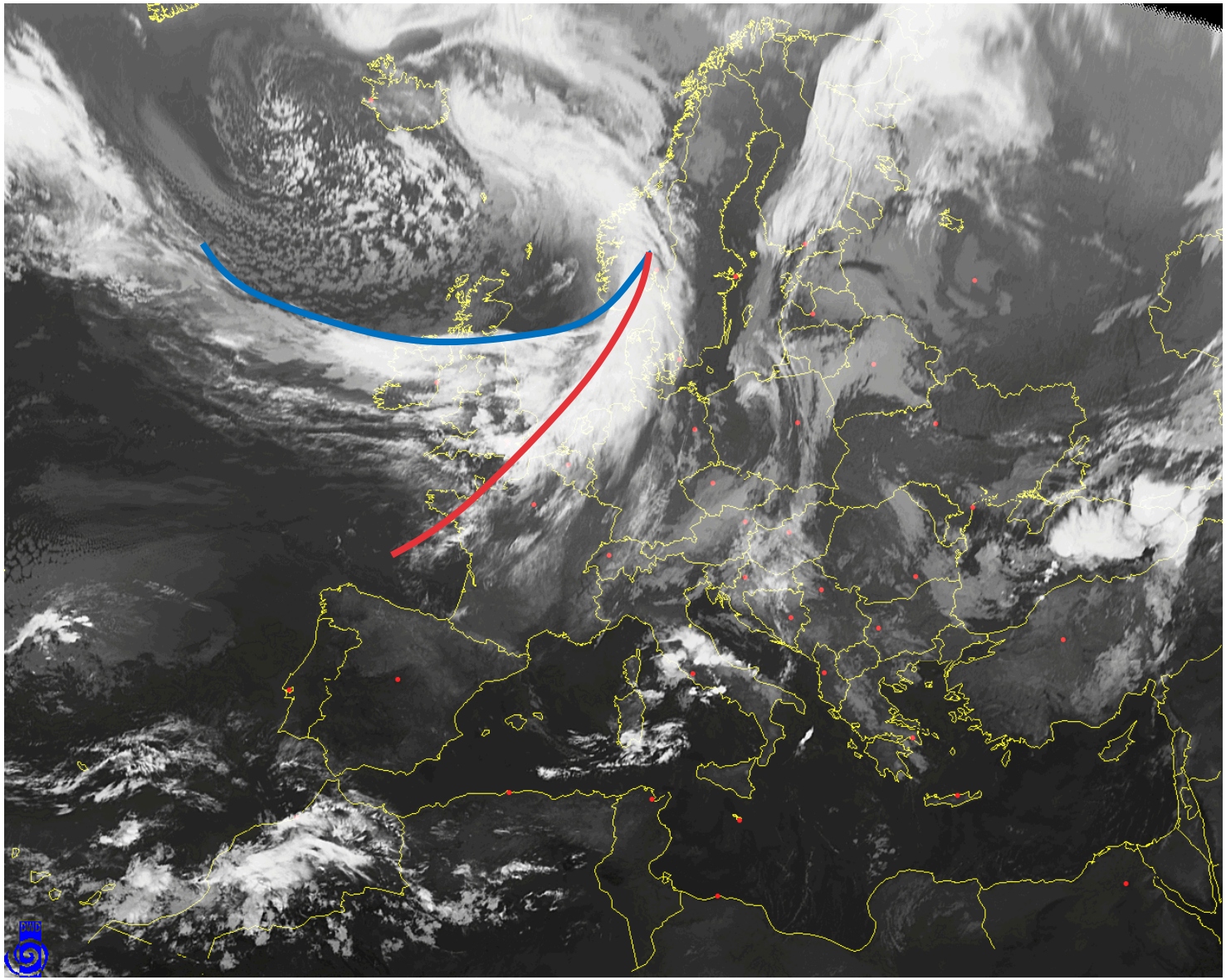


S3: Mast 38m
Lidar protoype at 28m
Forest height 24-28m

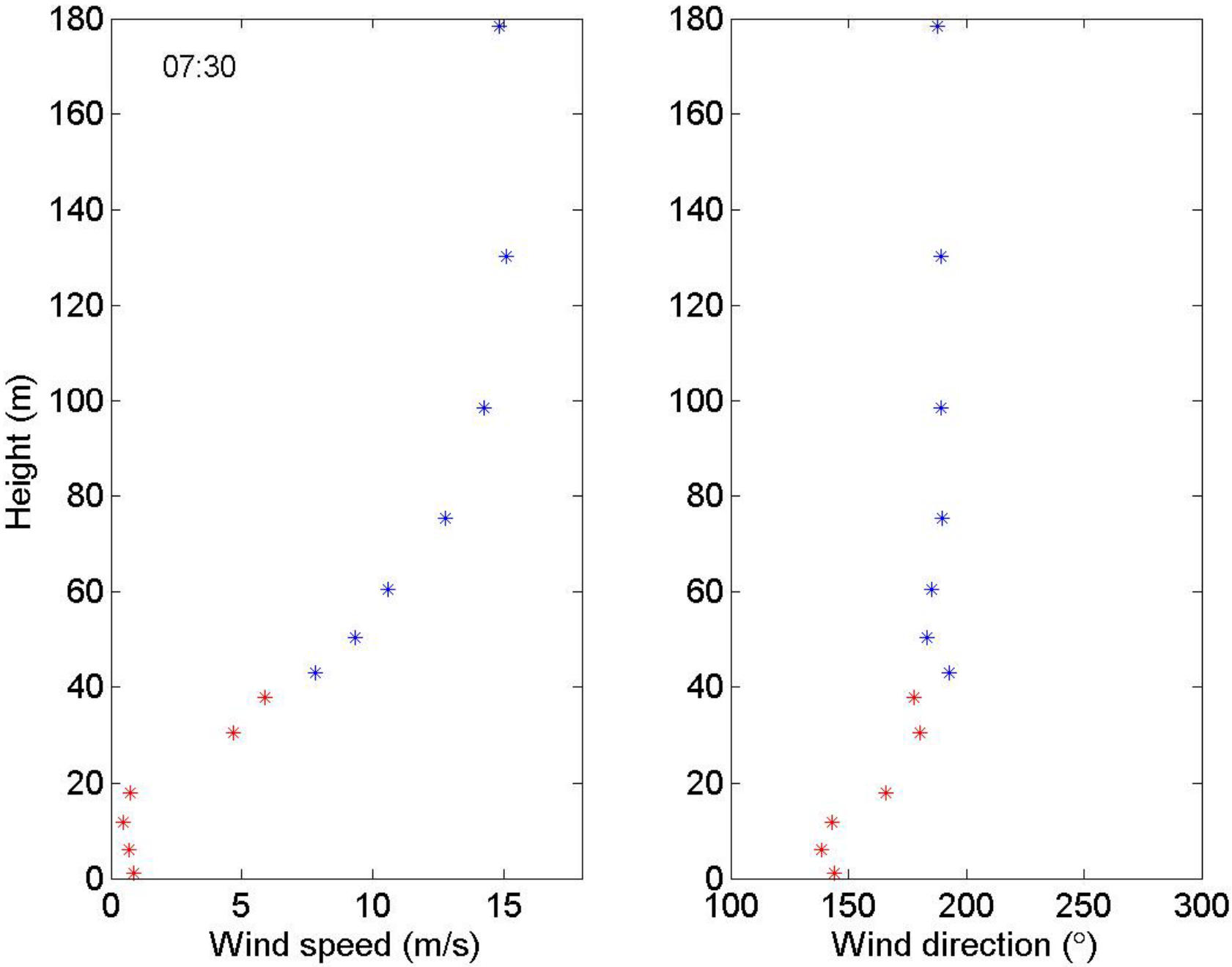
How much does it matter, where a large forest is located?



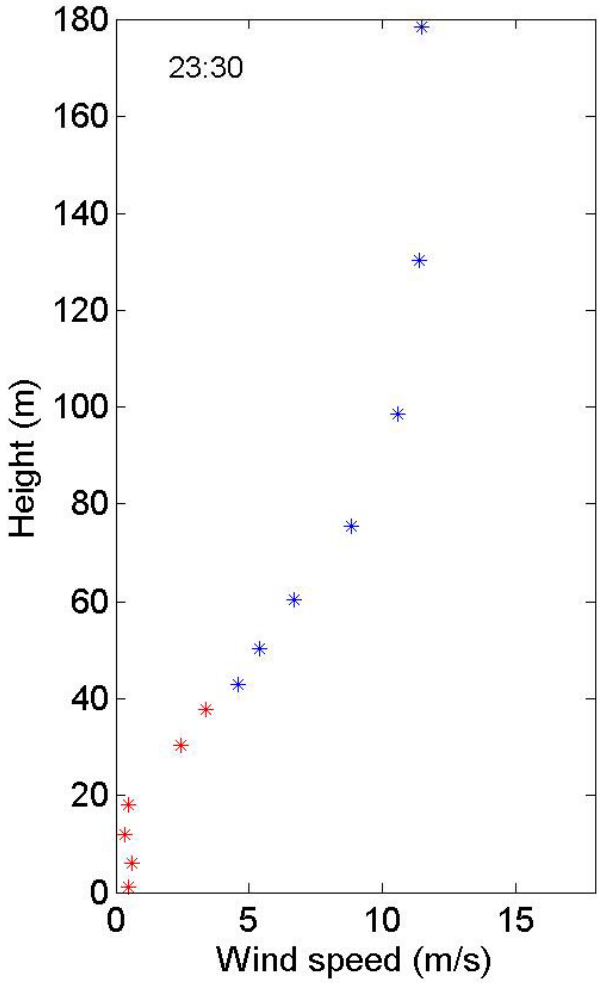
Satellite image of September 14th 00:00



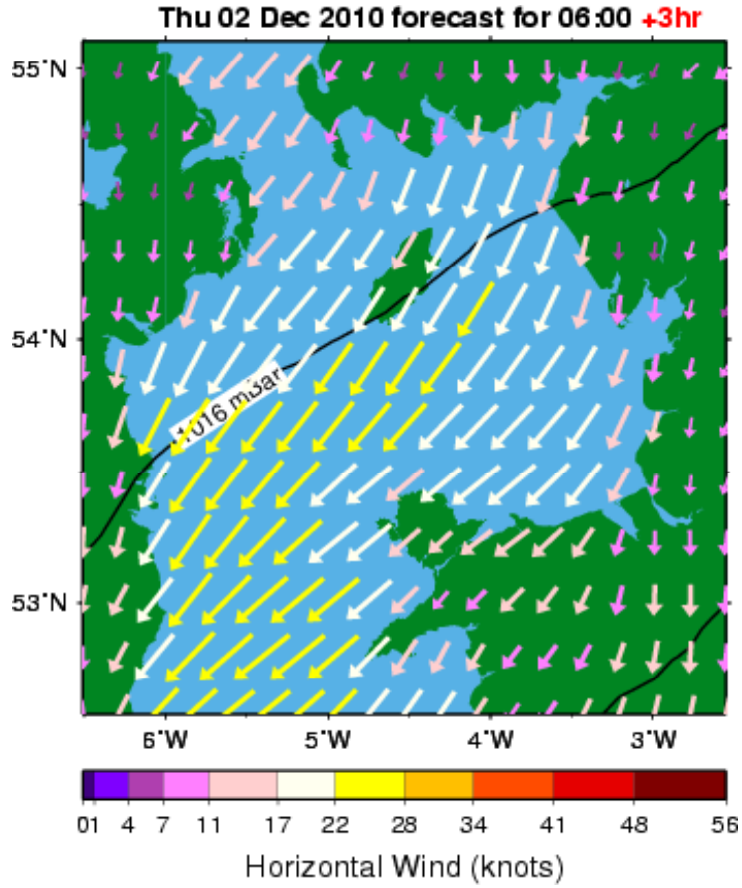
September 13th-14th, 2010



S3: hypothesis



Warm air from the sea is advected in over the relatively colder Swedish west coast. This creates a stably stratified atmosphere which suppresses the forest turbulence.



Summary

- **What characterizes the wind climate over a very large forest?**

  S1: high shear and turbulence intensity exceeding the IEC standard, regular events of fast changing wind speed.

  -> Possibility to make turbines taller or more robust.

- **How can we minimize the effect of trees on the turbine wind climate?**

  S2: improvement of micro-scale models by detailed near-forest experiment.

  -> Improve and run reliable micro-scale models to optimize the siting of turbines.

- **Does it matter where the large forest is located?**

  S3: yes! Preliminary results point to effects from areas >100km upstream of the site. More measurements are needed.

  -> Improve and run meso-scale models!

Thank you for your attention!

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- Meelis Mölder and Anders Lindroth at Lund University for use of data from site S1.
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